except in the Black Hills, a poor outlook for hay, and serious damage to small grains and other crops. The shipping of live stock from that section of the State has been excessive for the season. Many new settlers on land between the Missouri River and the eastern border of the Black Hills have been forced to move out. In parts of that section some of the seeds sown did not come up, owing to dry soil, and in places there was little new pasturage until near the middle of June. There were, of course, some localities that were favored with good showers and severe damage was averted. The eastern portion of the State fared somewhat better in the matter of rainfall, but there also insufficient moisture, with excessive heat and sunshine, caused serious damage to small grains and grasses in most counties, although there were limited localities where opportune rains prevented serious damage. In this section corn did well; it made unusual progress for the season on account of the warm nights. The grass crop, however, is short and under the most favorable conditions from now till the close of the season its yield can hardly be other than deficient. Owing to drought, and in some cases to lightning, fires were numerous in the Black Hills, and tree seeds sown on 1,000 acres in the national forest have not germinated properly. In all portions of the State conditions resulting from insufficient rainfall and excessive heat have been intensified by the dry state of the subsoil at the beginning of the season.

Nebraska.—June, 1911, was the warmest and driest recorded since 1876. The records in the State extend back to 1849, but previous to 1876 the number of stations was small. The 8 stations with a record in 1870 and the 3 in 1857 and 1859 indicate that the rainfall in those three years was as light, or probably lighter, in June than in the month just passed. The deficiency in rainfall was greatest in the southeastern section, as it averaged less than one-sixth of the normal and for considerable areas the total fall for the month was about half an inch. In parts of the central and northeastern sections the rainfall was normal, or slightly more than normal; this also was the case in the North Platte Valley. The cloudiness was much less than the average for the season. The mean for the entire State was 20 clear days, 9 partly cloudy, and 1 cloudy, a remarkable record for June in Nebraska.

Kansas.—The maximum temperatures were above 100° at every station. They were 110° or more in the Smoky Hill Valley from Gove County eastward, in the Solomon Valley from Osborne south, in the Republican Valley from Republic County south, and in the Blue Valley. In the Kansas Valley they ranged from 112° at the mouth of the Republican to 100° at Kansas City, Mo. The precipitation was below normal at all stations. The average number of rainy days was 3, the smallest number on record. No April, May, June, July, August, or September since records began has been as dry as June, 1911. Hot winds occurred on several days.

Iowa.—June is usually a wet and cool month in this section, but this year the temperatures were abnormally high and the rainfall was exceptionally light, except at a few stations in the extreme northern part of the State, where moderately heavy showers occurred on the night of the 25th. However, there was only one station that received an excess of moisture. The showers were light, widely scattered, and occurred at long intervals, except between the 14th and 17th, when they were quite general, but even then the amounts were small at most stations. The temperatures were high most of the time. The intense sunshine, and long-continued drought and the excessively high temperatures were damaging to all late crops except corn, and that was injured to some extent where the drought was most severe.

Missouri.—The month was the warmest and driest June of which we have a record. Both the heat and the dry weather began early in May, and high temperatures were continuous, save a few short interruptions. The areas in which the period of dry weather was broken by beneficial showers were scattered and limited in extent. At the close of the month pastures were as dry and brown as in late summer, and most crops had suffered. All streams were low and some were completely dry. In the southwestern part of the State it was reported that many wells had gone dry, and some of them were reported never to have failed before in the last 40 years or more.

THE EROSION OF SIOUX POINT, SOUTH DAKOTA.

By G. W. McDOWALL, Local Forecaster, United States Weather Bureau.

Within the past few years the Missouri River has encroached rapidly upon the South Dakota shore line for a distance of 3,000 yards above the junction of the Missouri and Big Sioux Rivers. Little attention was paid to the cutting till 1909, as no immediate loss was threatened except that of pasture and cultivable land. About that time it was feared that, unless checked, it might soon devour all of Sioux Point and reaching across the present bed of the Big Sioux destroy the Iowa shore as far back as the bluffs. This would include the fair grounds and boat-club properties as well as the electric and C., M. & St. P. Railway tracks, and cause the inundation of lowlands on both sides of the Big Sioux for one-half mile upstream.

In 1910 an appropriation of $32,500 was granted by the Government for the purpose of shore protection along this bank on condition that an equal amount be raised by local subscription. The money was not raised, as it was thought the channel would automatically shift southward, but cutting continued at such a rapid rate that conditions became critical during the spring of 1911, and the conclusion was unavoidable that immediate action was necessary to save the threatened properties. A delegation was sent to Washington in June, and an increased appropriation was secured, leaving but $16,000 to be raised locally. About $11,000 of this has been pledged and the remainder is in sight. It is intended to protect the shore by riprapping from Gumbo Point to Sioux Point, a distance of about 3,500 yards. A woven mat, 75 to 80 feet wide, will be used, one side being ballasted with rock and sunk in the stream, the other reaching up over the bank. The bank will then be rock paved over its entire face. About 1,500 yards from Sioux Point a dike will be built to deflect the current. Requisition has been made for the necessary materials and these are being gathered as rapidly as possible. Plans are under way to commence construction within a few days and the completion of the work is expected this summer.

The soil of the threatened bank is of gumbo and sand composition and offers little resistance to the encroaching stream. Nearer the junction of the streams the shore is heavily wooded and the work of the river has been materially hindered by the tree roots. The bank rises almost 15 feet above the present surface of the water till within 300 yards of Sioux Point, whence it is little more than 3 feet above the stream. A river stage of 14 feet would submerge this lowland and it would be swept away almost at once. Another source of danger is the old river bed paralleling the shore line for several hundred yards and only distant therefrom a few rods. Upon the first breach in this wall the water will pour through the old channel and it will be too late to save Sioux Point.

FLOODS OF THE UPPER MISSOURI RIVER.

By C. D. REED, Local Forecaster, United States Weather Bureau.

Little has been published on the subject of flood conditions and fluctuations of river stages in the upper Missouri River. It is therefore hoped that this short article, treating of some phases of the subject, may be interesting to those who are now trying to revive navigation, to those who are engaged in bank protection and other works of construction along the stream, and to the many farmers who venture to till the broad acres of unusually fertile land subject to occasional overflow that lie adjacent to the river through several States.

The conclusions reached proceed from 10 years' study of the stream, during a considerable portion of which the writer was in charge of the river and flood service of the Weather Bureau on the Missouri River and tributaries at and above Sioux City, Iowa. The scope of the paper will therefore be confined to that portion of the river.

The drainage area of the Missouri River above Sioux City includes four-fifths of Montana, considerable territory in the Provinces of Alberta and Saskatchewan in

Canada, one-half of Wyoming, three-fifths of North Dakota, nearly all of South Dakota, one-sixth of Nebraska, and small portions of Minnesota and Iowa. A little more than half of the drainage area referred to lies above Williston, N. Dak., and has an average annual precipitation of about 13.6 inches. The drainage area between Williston and Sioux City has an average annual precipitation of about 20.2 inches. Excluding Wyoming, the entire drainage area above Sioux City has about 46 per cent of its annual precipitation in the three months of May, June, and July, and the departures from this percentage are remarkably small at individual stations. Above Williston the precipitation for the three months is about 6.25 inches, and between Williston and Sioux City it is about 9.30 inches, or about 50 per cent greater in the lower than in the upper half of the area under consideration. The precipitation, including melted snow that occurs in the mountains at the headwaters, is known to be much heavier in the course of the year, but the area that remains above the snow line in June or even in the latter part of May is very small as compared with the entire drainage basin.

As affecting high river stages, it is important to note that in general rainfalls of less than 1 inch in 24 hours do not swell the streams greatly, because the water is held by the soil and slowly evaporated or used by vegetation or percolates gradually into the streams. However, rainfalls of half an inch per day, if continued for four or five consecutive days, will sometimes cause large rises in the streams. Rainfalls equaling or exceeding 1 inch in 24 hours are not nearly so frequent in the drainage area above Williston as below.

Under these conditions of rainfall the Missouri nearly always reaches its maximum stage for the year in the month of June. At Sioux City the average date of the maximum stage for the last 20 years is June 21. It has occurred as early as the last of May and as late as the last of July. At stations near the headwaters the lowest stage occurs in September, after which a gradual rise takes place till the following March or April. At Bismarck the lowest stage is reached in October, while at Pierre it is delayed till November, and at Sioux City till December.

At most stations there is a secondary maximum stage at the time of the spring break-up, which occurs in the extreme upper river and below Pierre in March, but from above Pierre to about Wolf Point, Mont., the break-up is frequently delayed till April. When the spring rise in the extreme upper river is not too sudden, the ice from Wolf Point to Bismarck frequently rises with the water as much as 10 feet and then settles back, as the rise passes, without breaking up. Between the spring and summer maxima there is a noticeable secondary minimum. While the spring maximum is usually of secondary importance, it must not be forgotten that the highest known stages at most stations from Wolf Point, Mont., to St. Joseph, Mo., occurred in April, 1881. This was due to a much delayed approach to spring conditions followed by a sudden rise to normal temperature, acting upon a large accumulation of snow and ice. The ice was so thick that many large gorges formed and some entire villages were swept away. A similar condition prevailed in the vicinity of Vermilion, S. Dak., in February and March, 1907.

In order to disclose the causes of the so-called "June rise," the following account is given of the two most notable rises that have occurred in recent years.

During the spring and early summer of 1905, the upper Missouri and its tributaries were abnormally low. In the first five days of July, heavy rains fell in South Dakota and the southern half of North Dakota, which caused the highest summer stages on record, from Pierre on the 4th to below Sioux City on the 7th. Throughout the season, at Bismarck and above, the river remained abnormally low. It is interesting to note that the interval from the first day that the rain fell in large quantities, which was on the 2d, until the flood crest passed Sioux City, about midnight of the 6th, was less than six days.

The other large rise to which attention is invited was in June, 1908. During the first six days of the month the rainfall in the foothills and the central portion of Montana averaged about 3.5 inches, many stations having from one-half to three-fourths of their normal annual amounts in that short period of six days. For a long distance above and below Fort Benton, Mont., this produced a flood unprecedented in the records of white men or the traditions of Indians. The crest of the flood passed Fort Benton between the mornings of the 6th and 7th, and boating was good all over town. At the mouth of the Teton and Marias Rivers, just below Fort Benton, it is learned from unofficial sources that the water reached 32 feet above low-water mark. Damage to the amount of hundreds of thousands of dollars occurred in this section of the river valley, and more or less damage was reported as far down as Wolf Point. The flood was augmented by heavy rains in eastern Montana and western North Dakota, but in spite of this fact the stage reached at Bismarck was only slightly higher than the highest previously recorded summer stage. Further augmentation from heavy rains took place as the flood passed on down, yet at Pierre and below the crest stage was not unusually high, and at Sioux City it was just the same as for the two preceding years. From the time the heavy rains began in Montana till the flood crest passed Sioux City was 23 days. From the time the crest passed Fort Benton till it passed Sioux City was about 17 days. This was longer than usual because of the heavy rains that were coincident with or slightly in the rear of the original crest. Ordinarily the time required for a flood crest to move from Fort Benton to Wolf Point is about five days; from Wolf Point to Bismarck, three days; from Bismarck to Pierre, about two days; from Pierre to Running Water, S. Dak., one day; and from Running Water to Sioux City, one day. This makes a total of about 12 days from Fort Benton to Sioux City.

From a careful examination of several other summer rises no instance was found where it could not be traced to an adequate current rainfall cause. This is at variance with the commonly accepted view of steamboat men and others who have lived along the river for a generation. They nearly all assert that the principal cause of the "June rise" is the melting of the accumulated snow in the mountains at the headwaters, brought about by the warm weather in the latter part of May and during June. This does not seem probable when we reflect that the unprecedented flood in Montana in 1908 could scarcely be traced below Pierre. As has already been pointed out, the area that remains above the snow line on June 1 is a very small portion of the total drainage area. The conclusion reached in this connection is that the controlling factor in flood stages in summer at, and for a long distance above, Sioux City, is the current rainfall, and that the water resulting from the melting of the accumulated snow is almost a negligible quantity. This is further borne out by the fact that the average

annual range of river stages at Fort Benton, past which much of the mountain snow contingent must flow, is only 5.7 feet.

From this it follows that the record of precipitation on the daily weather map in connection with river-gauge readings affords the only rational basis for forecasting river stages, and that successful forecasts of river stages in the middle Missouri can not be made for longer periods than a few days, or possibly in some cases ten days, in advance.

Relative to the possibility of reviving navigation on the Missouri River, it is interesting to note whether or not the stage of the river averages higher or lower now than formerly. A tabulation of the stages at Sioux City in the last two 10-year periods, shows in general slightly higher stages in the latter period than in the former. The largest increase is in the months of August, September, and October. This suggests the possibility that the cultivation of the soils of the western prairies may have increased their power to absorb and retain rainfall so that more of the rainfall reaches the streams by the slow process of percolation through the soil instead of by rapid surface run-off. On the other hand, the mere tabulation of river stages may not tell the whole story with regard to the volume of water that passes a given station. Erosion, silting, and other changes probably cause variations in the discharge with a given river stage.

Chart I shows the total rainfall during the first five days in July, 1905, which was the cause of the flood which followed.

Chart II shows the total rainfall during the first six days of June, 1908, which caused an unprecedented flood in the upper river but no unusual stages below Bismarck.

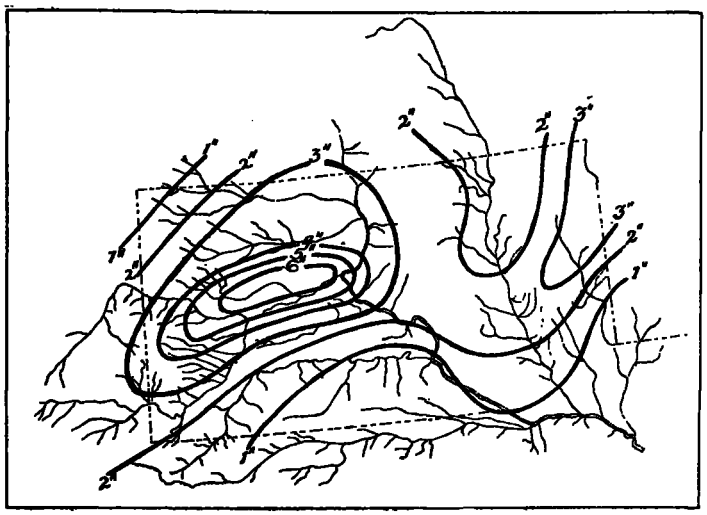

CHART I.—Rainfall during the first five days in July, 1905, in South Dakota.

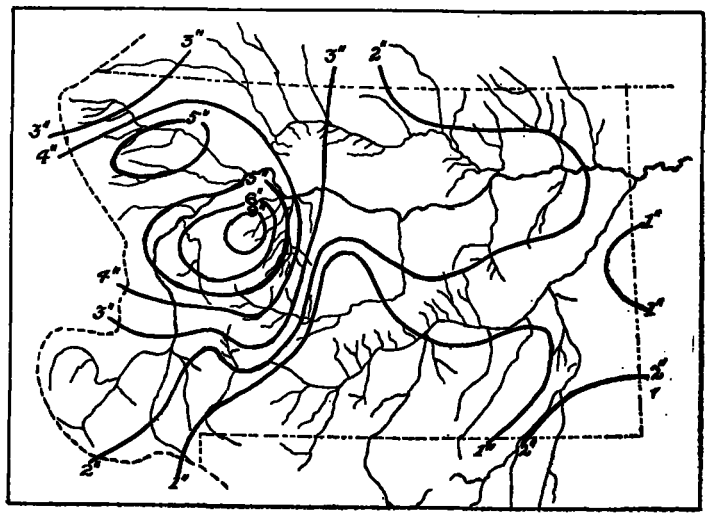

CHART II.—Rainfall during the first six days in June, 1908, at the headwaters of the Missouri River.